Article 63

Chapter 1 of the Maryland Department of the Envionment Stormwater Manual

Why Stormwater Matters

Urban development has a profound influence on the quality of local streams. To start, development dramatically alters the local hydrologic cycle (see Figure 1). The hydrology of a site changes during the initial clearing and grading that occur during construction. Trees that had intercepted rainfall are removed, and natural depressions that had temporarily ponded water are graded to a uniform slope. The spongy humus layer of the forest floor that had absorbed rainfall is scraped off, eroded or severely compacted. Having lost its natural storage capacity, a cleared and graded site can no longer prevent rainfall from being rapidly converted into stormwater runoff.

The situation worsens after construction. Roof tops, roads, parking lots, driveways and other impervious surfaces no longer allow rainfall to soak into the ground. Consequently, most rainfall is directly converted into stormwater runoff. This phenomenon is illustrated in Figure 2, which shows the increase in the volumetric runoff coefficient (R_v) as a function of site imperviousness. The runoff coefficient expresses the fraction of rainfall volume that is converted into stormwater runoff. As can be seen, the volume of stormwater runoff increases sharply with impervious cover. For example, a one acre parking lot can produce 16 times more stormwater runoff than a one acre meadow each year.

The increase in stormwater runoff can be too much for the existing drainage system to handle. As a result, the drainage system is often "improved" to rapidly collect runoff and quickly convey it away (using curb and gutter, enclosed storm sewers, and lined channels). The stormwater runoff is subsequently discharged to downstream waters, such as streams, reservoirs, lakes or estuaries.

Declining Water Quality

Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles, or windblown in from adjacent areas. During storm events, these pollutants quickly wash off, and are rapidly delivered to downstream waters. Some common pollutants found in urban stormwater runoff are profiled in Table 1 and include the following:

Nutrients. Urban runoff has elevated concentrations of both phosphorus and nitrogen, which can enrich streams, lakes, reservoirs and estuaries (known as eutrophication). In particular, excess nutrients have been documented to be a major factor in the decline of Chesapeake Bay. Excess nutrients promote algal growth that blocks sunlight from reaching underwater grasses and depletes oxygen in bottom waters. Urban runoff has been identified as a key and controllable source of nutrients.

Figure 1: Water Balance at a Developed and Undeveloped Site

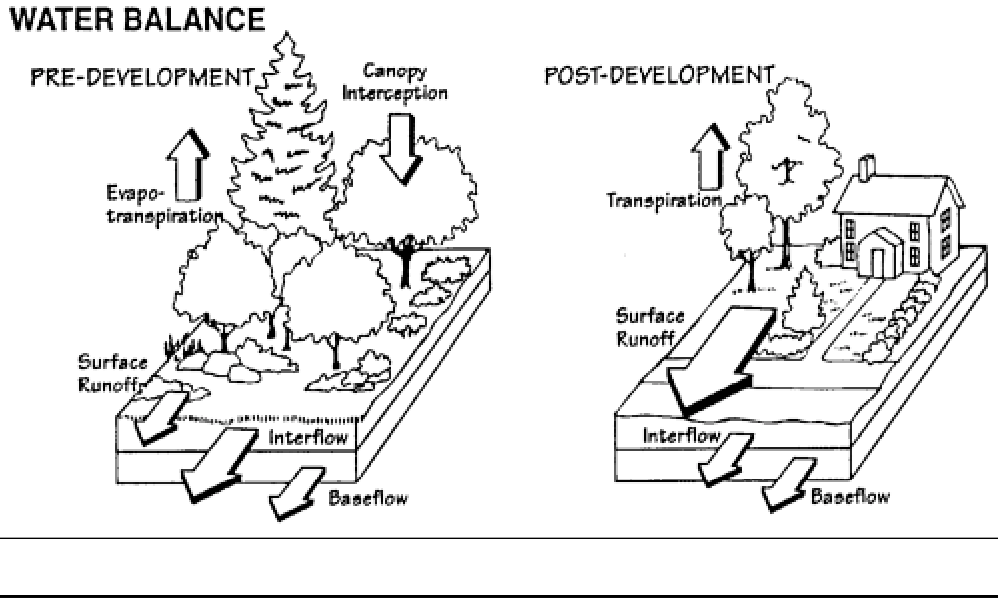

Table 1: Typical Pollutant Concentrations Found in Urban Stormwater

Typical Pollutants Found in Stormwater Runoff (Data source)	Units	Average Concentration (1)
Total Suspended Solids (a)	mg/l	80
Total Phosphorus (b)	mg/l	0.30
Total Nitrogen (a)	mg/l	2.0
Total organic Carbon (d)	mg/l	12.7
Fecal Coliform Bacteria (c)	MPN/100 ml	3600
E. coli Bacteria (c)	MPN/100 ml	1450
Petroleum Hydrocarbons (d)	mg/l	3.5
Cadmium (e)	ug/l	2
Copper (a)	ug/l	10
Lead (a)	ug/l	18
Zinc (e)	ug/l	140
Chlorides (f) (winter only)	mg/l	230
Insecticides (g)	ug/l	0.1 to 2.0
Herbicides (g)	ug/l	1 to 5.0

(1) these concentrations represent *mean or median* storm concentrations measured at typical sites, and may be greater during individual storms. Also note that mean or median runoff concentrations from *stormwater hotspots* are 2 to 10 times higher than those shown here. Units = mg/l = milligrams/liter, g/l = micrograms/liter.

Data Sources: (a) Schueler (1987) (b) Schueler (1995), (c) Schueler (1997), (d) Rabanal and Grizzard (1996) (e) USEPA (1983) (f) Oberts (1995) (g) Schueler, (1996)

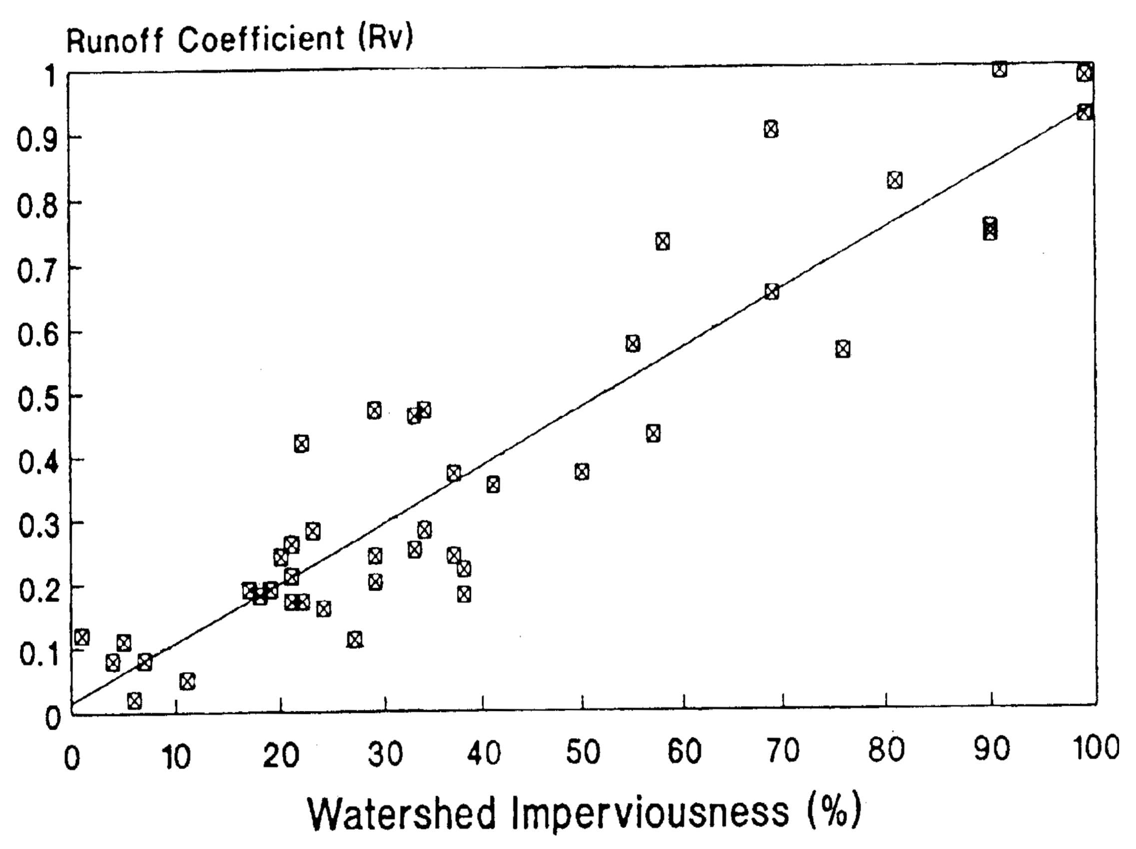

Figure 2: Relationship Between Impervious Cover and the Volumetric Runoff Coefficient

Suspended solids. Sources of sediment include washoff of particles that are deposited on impervious surfaces and the erosion of streambanks and construction sites. Both suspended and deposited sediments can have adverse effects on aquatic life in streams, lakes and estuaries. Sediments also transport other attached pollutants.

Organic Carbon. Organic matter, washed from impervious surfaces during storms, can present a problem in slower moving downstream waters. As organic matter decomposes, it can deplete dissolved oxygen in lakes and tidal waters. Low levels of oxygen in the water can have an adverse impact on aquatic life.

Bacteria. Bacteria levels in stormwater runoff routinely exceed public health standards for water contact recreation. Stormwater runoff can also lead to the closure of adjacent shellfish beds and swimming beaches and may increase the cost of treating drinking water at water supply reservoirs.

Hydrocarbons. Vehicles leak oil and grease which contain a wide array of hydrocarbon compounds, some of which can be toxic at low concentrations to aquatic life.

Trace Metals. Cadmium, copper, lead and zinc are routinely found in stormwater runoff. These metals can be toxic to aquatic life at certain concentrations, and can also accumulate in the sediments of streams, lakes and the Chesapeake Bay.

Pesticides. A modest number of currently used and recently banned insecticides and herbicides have been detected in urban streamflow at concentrations that approach or exceed toxicity thresholds for aquatic life.

Chlorides. Salts that are applied to roads and parking lots in the winter months appear in stormwater runoff and meltwater at much higher concentrations than many freshwater organisms can tolerate.

Thermal Impacts. Impervious surfaces may increase temperature in receiving waters, adversely impacting aquatic life that requires cold and cool water conditions (e.g., trout).

Trash and Debris. Considerable quantities of trash and debris are washed through the storm drain networks. The trash and debris accumulate in streams and lakes and detract from their natural beauty.

Diminishing Groundwater Recharge and Quality

The slow infiltration of rainfall through the soil layer is essential for replenishing groundwater. The amount of rainfall that recharges groundwater varies, depending on the slope, soil, and vegetation. Some indication of the importance of recharge is shown in Table 2, which shows Natural Resources Conservation Service (NRCS) regional estimates of average annual recharge volume, based on soil type.

Table 2: NRCS Estimates of Annual Recharge Rates, Based on Soil Type

Hydrologic Soil Group (NRCS)	Average Annual Recharge Volume
A Soils	18 inches/year
B Soils	12 inches/year
C Soils	6 inches/year
D Soils	3 inches/year

Average annual rainfall is about 40 inches per year across Maryland.

Groundwater is a critical water resource across the state. Not only do many residents depend on groundwater for their drinking water, but the health of many aquatic systems is also dependent on its steady discharge. For example, during periods of dry weather, groundwater sustains flows in streams and helps to maintain the hydrology of non-tidal wetlands (Figure 3). Because development creates impervious surfaces that prevent natural recharge, a net decrease in groundwater recharge rates can be expected in urban watersheds. Thus, during prolonged periods of dry weather, streamflow sharply diminishes. In smaller headwater streams, the decline in stream flow can cause a perennial stream to become seasonally dry.

Urban land uses and activities can also degrade *groundwater quality,* if stormwater runoff is directed into the soil without adequate treatment. Certain land uses and activities are known to produce higher loads of metals and toxic chemicals and are designated as *stormwater hotspots*. Soluble pollutants, such as chloride, nitrate, copper, dissolved solids and some polycyclic aromatic hydrocarbons (PAHs) can migrate into groundwater and potentially contaminate wells. Stormwater runoff should never be infiltrated into the soil if a site is a designated hotspot.

Degradation of Stream Channels

Stormwater runoff is a powerful force that influences the geometry of streams. After development, both the frequency and magnitude of storm flows increase dramatically (Figure 4). Consequently, urban stream channels experience more bankfull and sub-bankfull flow events each year than they had prior to development.

As a result, both the bed and bank of a stream are exposed to highly erosive flows more frequently and for longer periods. Streams typically respond to this change by increasing their cross-sectional area to handle the more frequent and erosive flows either by channel widening or down cutting, or both. The stream enters a highly

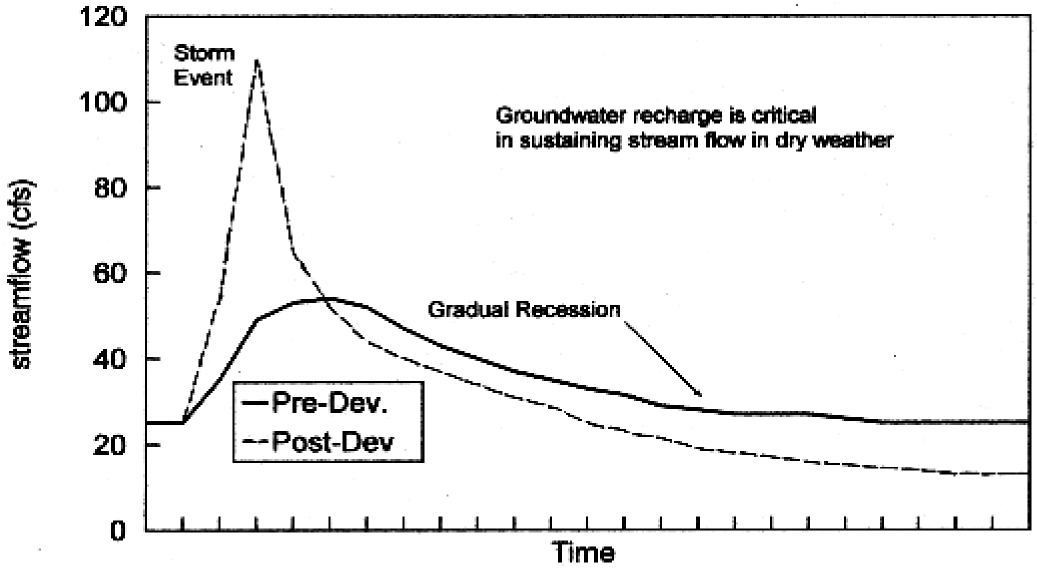

Figure 3: Decline in Streamflow Due to Diminished Groundwater Recharge

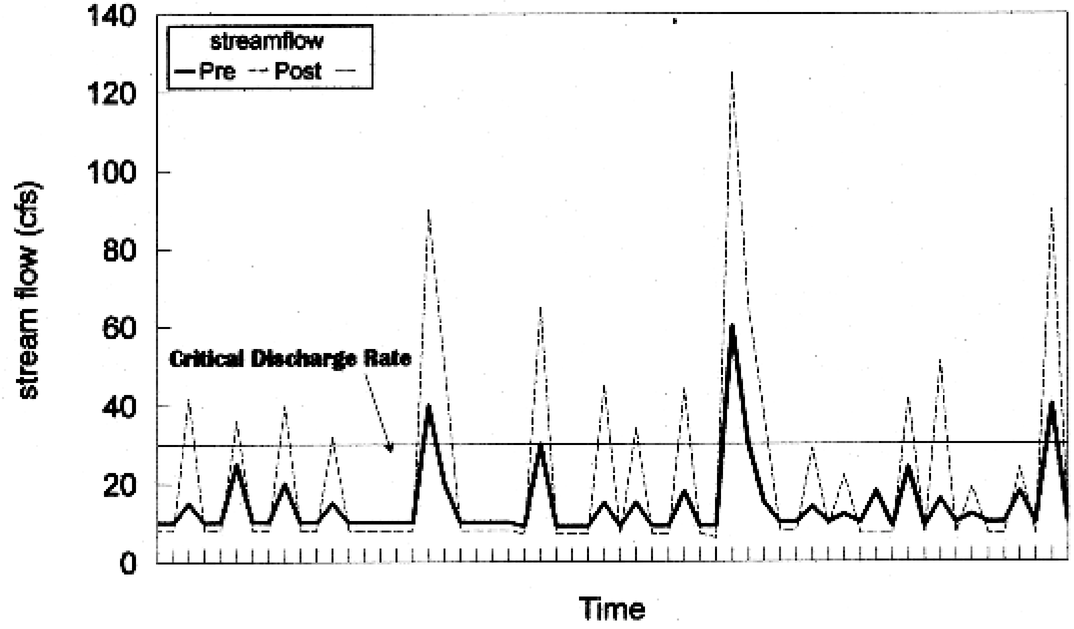

Figure 4: Increased Frequency of Critical Erosive Velocities in a Stream Channel after Development

unstable phase, and experiences severe streambank erosion and habitat degradation. In this phase, the stream often experiences some of the following changes:

- Rapid stream widening
- Increased streambank and channel erosion
- Decline in stream substrate quality (through sediment deposition and embedding of the substrate)
- Loss of pool/riffle structure in the stream channel
- Degradation of stream habitat structure
- Creation of fish barriers by culverts and other stream crossings.

The decline in the physical habitat of the stream, coupled with lower base flows and higher stormwater pollutant loads, has a severe impact on the aquatic community. Recent research has shown the following changes in stream ecology:

- Decline in aquatic insect and freshwater mussel diversity
- Decline in fish diversity
- Degradation of trout habitat

Traditionally, communities have attempted to provide some measure of channel protection by imposing the two-year storm peak discharge control requirement, which requires that the discharge from the two-year post-development peak rates be reduced to pre-development levels. Recent research and experience however, indicates that the two-year peak discharge criterion is not capable of protecting downstream channels from erosion. In some cases, the two-year storm criteria may actually accelerate streambank erosion, because it exposes the channel to a longer duration of erosive flows than it would have otherwise received.

Increased Overbank Flooding

Flow events that exceed the capacity of the stream channel spill out into the adjacent floodplain. These are termed "overbank" floods, and can damage property and downstream drainage structures.

While some overbank flooding is inevitable and even desirable, the historical goal of drainage design in many communities has been to maintain pre-development peak discharge rates for both the two and ten-year frequency storm after development, thus keeping the level of overbank flooding the same over time. This prevents costly damage or maintenance for culverts, drainage structures, and swales.

Overbank floods are ranked in terms of their statistical return frequency. For example, a flood that has a 50% chance of occurring in any given year is termed a "two year" flood. The two-year storm is also known as the "bankfull flood," as researchers have demonstrated that most natural stream channels in the state have just enough capacity to handle the two-year flood before spilling out into the floodplain. In Maryland, about three to 3.5 inches of rain in a 24-hour period produces a two-year or bankfull flood. This rainfall depth is termed the two-year design storm.

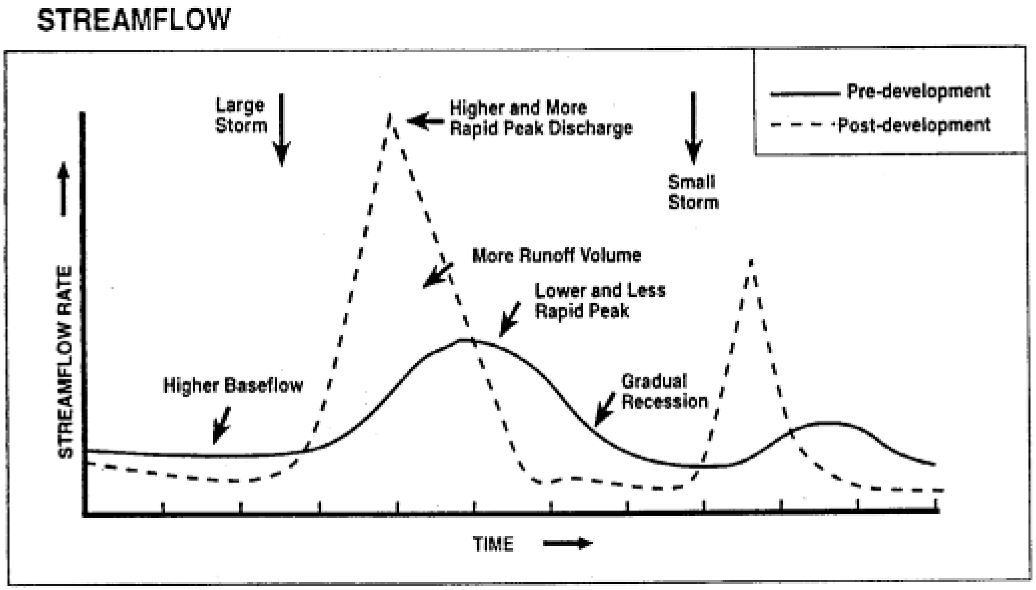

Figure 5: Change in Hydrograph Following Development

Similarly, a flood that has a 10% chance of occurring in any given year is termed a "10-year flood." A 10-year flood occurs when a storm event produces about 4.5 to 5.5 inches of rain in a 24- hour period. Under traditional engineering practice, most channels and storm drains in Maryland are designed with enough capacity to safely pass the peak discharge from the 10-year design storm.

Urban development increases the peak discharge rate associated with a given design storm, because impervious surfaces generate greater runoff volumes and drainage systems deliver it more rapidly to a stream. The change in post-development peak discharge rates that accompany development is profiled in Figure 5.

Floodplain Expansion

The level areas bordering streams and rivers are known as floodplains. Operationally, the floodplain is usually defined as the land area within the limits of the 100-year storm flow water elevation. The 100-year storm has a 1% chance of occurring in any given year. In Maryland, a 100-year flood occurs after about seven to eight inches of rainfall in a 24-hour period (i.e., the 100-year storm). These floods can be very destructive, and can pose a threat to property and human life.

Floodplains are natural flood storage areas and help to attenuate downstream flooding. Floodplains are very important habitat areas, encompassing riparian forests, wetlands, and wildlife corridors. Consequently, all local jurisdictions in Maryland restrict or even prohibit new development within the 100-year floodplain to prevent flood hazards and conserve habitats. Nevertheless, prior development that has occurred in the floodplain remains subject to periodic flooding during these storms.

As with overbank floods, development sharply increases the peak discharge rate associated with the 100-year design storm. As a consequence, the elevation of a stream's 100 year floodplain becomes higher and the boundaries of its floodplain expand (see Figure 6). In some instances, property and structures that had not previously been subject to flooding are now at risk. Additionally, such a shift in a floodplain's hydrology can degrade wetlands and forest habitats.

Summary

The many changes in hydrology and water quality caused by urban development present the stormwater manager with hard choices about which storm events to treat, and which stormwater practices with which to treat them. These are described in the ensuing articles. ***-TRS***

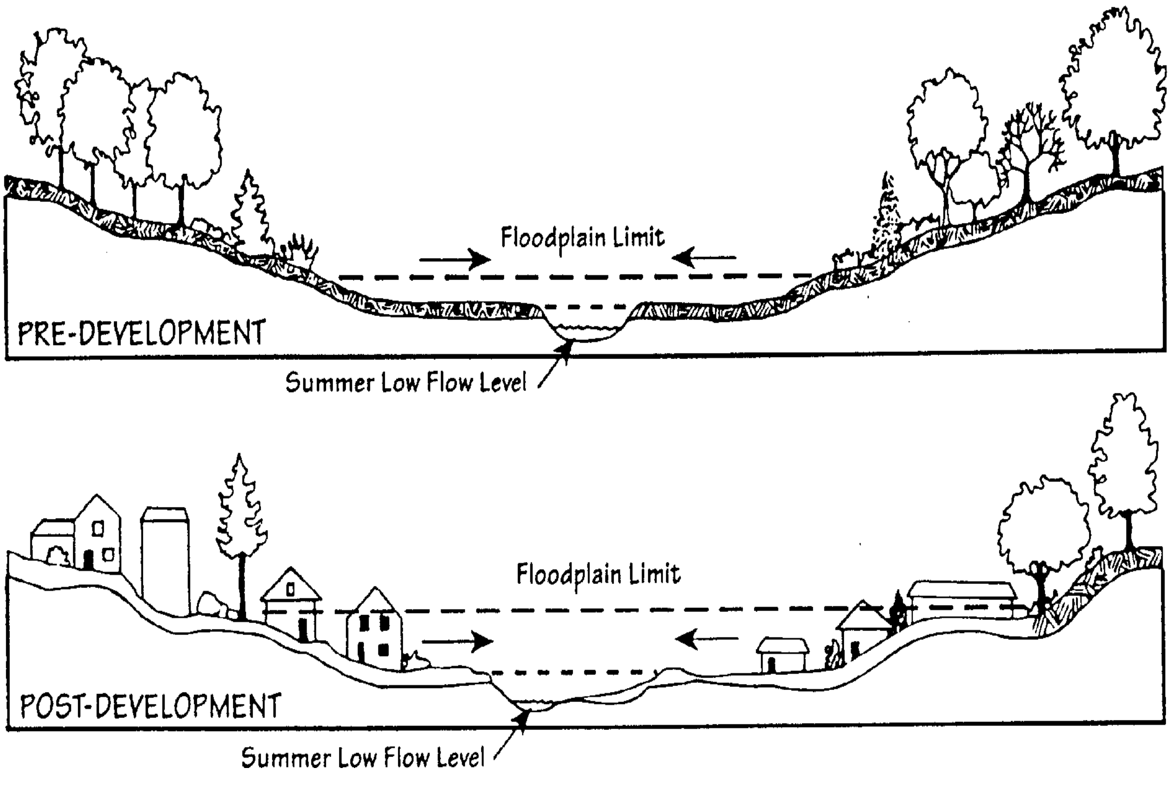

Figure 6: Change in Floodplain Elevations